

APPENDIX F

CALCULATIONS PACKAGES

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F.1

UNIVERSAL SOIL LOSS CALCULATIONS

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F.1

UNIVERSAL SOIL LOSS CALCULATIONS

Erosion at the proposed Transuranic (TRU) Waste Treatment Project site was modeled using the Revised Universal Soil Loss Equation (RUSLE), Version 1.06 (Toy and Foster 1998). RUSLE is a set of mathematical equations that estimate soil loss resulting from interrill and rill erosion (Lal 1994). RUSLE utilizes the basic formula of the Universal Soil Loss Equation as developed by Wischmeier and Smith (1978):

$$A = R * K * LS * C * P$$

where:

A = average annual soil loss in tons per acre,
R = rainfall/runoff erosivity,
K = soil erodibility,
LS = hillside length and steepness,
C = cover management,
P = soil conservation practices.

For the purposes of this analysis, the RUSLE was run assuming three scenarios. For each of the three scenarios, the R, K, and LS factors values did not vary. The R factor (180) used the climatic database for Knoxville, Tennessee. The initial K factor (0.37) was selected from soils mapped in Anderson County, Tennessee (Moneymaker 1981), with similar lithology and parent material to soils mapped at the TRU site. The RUSLE further modifies the initial K values based on variations in climatic data (R factor) through the year. The LS value was calculated from RUSLE using a slope with a total length of 91.5 m (300 ft) and a 30 % slope.

The first scenario assumed a worst-case condition, in which virtually no cover management practices were utilized to protect bare soils at the proposed construction site from the erosive energy of precipitation. The second-case scenario was run under the assumption that minimal cover management and conservation practices (some mulching to protect bare soil from precipitation) were utilized to provide a small amount of erosion prevention. The third scenario assumed intensive conservation practices (mulching, silt fences, and sediment basins) to provide maximum protection from erosion.

Results of the model runs for scenarios 1, 2, and 3 are displayed in Table 1 below. Based on Scenario 1 (no cover management practices), predicted soil loss could be expected to be as high as 404.7 metric tons per hectare per year (180.5 tons per acre per year). The tolerable soil loss published for similar soils is 6.7 metric tons per hectare per year (3 tons per acre per year) (Moneymaker 1981). Based on Scenario 2 (minimal cover management practices), predicted soil loss would be somewhat less than for Scenario 1, but could still as high as 188.8 metric tons per hectare per year (84.2 tons per acre per year). The predicted soil loss is still much higher than the published tolerance value. In Scenario 3 (intensive cover management practices), predicted soil loss would be further reduced to 2.2 metric tons per hectare per year (1.0 ton per acre per year), well within the published tolerable limits.

Table 1. Predicted soil loss at proposed TRU waste facility under varying degrees of cover management practices

Scenario	R factor	K factor	LS factor	C factor	P factor	A
1	180	0.359	12.53	0.2229	1.00	180.5
2	180	0.359	12.53	0.1040	1.00	84.2
3	180	0.359	12.53	0.0011	1.00	1.0

REFERENCES

- Lal, R. 1994. *Soil Erosion Research Methods*, Soil and Water Conservation Society, Ames, Iowa, and St. Lucie Press, Del Ray, Florida, second edition, 340 pp.
- Moneymaker, R. H. 1981. *Soil Survey of Anderson County, Tennessee*, U.S. Department of Agriculture, Soil Conservation Service in cooperation with Tennessee Agricultural Experiment Station, 165 pp. plus maps.
- Toy, T. J., and G. R. Foster. *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) (Version 1.06) on Mined Lands, Construction Sites, and Reclaimed Lands*, Department of Interior, Office of Surface Mining, Denver, Colorado.
- Wischmeier, W. H., and D. D. Smith 1978. *Predicting Rainfall Erosion Losses – a Guide to Conservation Planning*, U.S. Department of Agriculture, Agriculture handbook No. 537, 58 pp.

APPENDIX F.2

ECOLOGICAL IMPACTS FROM A SEISMICALLY INDUCED BREACH OF THE MELTON VALLEY STORAGE TANKS

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F.2

IMPACTS TO AQUATIC BIOTA FROM A SEISMICALLY INDUCED BREACH OF THE MELTON VALLEY STORAGE TANKS

ASSUMPTIONS

As a reasonable worst case, it was assumed that the release from the ruptured tank is rapid, so the tank contents would rapidly be transported to Melton Branch. Therefore, undiluted concentrations of radionuclides were used for the initial exposure and risk calculations. Releases of radionuclides were evaluated for two tanks, Tank 26, which has the highest gross beta/gamma, and Tank 28, which has the highest gross alpha (Keeler et al. 1996). It was assumed that White Oak Lake, with an area of 6 to 8 hectares (ha) (Loar 1992), has a volume of approximately 3 to 6 million cubic feet and an average daily flow of 1.3 million cubic feet. The tank volume of 50,000 gal is equal to approximately 6,400 cubic feet, resulting in a dilution factor of about 450 to 900 in White Oak Lake.

Radiological benchmarks for exposure of aquatic biota to radionuclides in water and sediment have been developed by Bechtel Jacobs (1998) and were used to evaluate exposure of aquatic biota to radionuclides in water from the Melton Valley tanks. Dietary and ingestion rate information for herons is presented in Table 1. Radionuclide decay energies and absorption factors are presented in Table 2.

Table 1. Receptor Parameters for Great Blue Heron

Parameter	Definition	Receptor: Great blue heron (<i>Ardea herodias</i>)	
		Value	Reference/Notes
BW	Body weight (kg)	2.39	Arithmetic mean, adult, both sexes, location not stated (EPA 1993)
HR	Home range (km)	3.1	Foraging distance, mean, adults, both sexes, South Dakota, stream (EPA 1993)
TUF	Temporal use factor	1	Will be 1 unless a specific value exists for a receptor
IR _F	Food ingestion rate (g/g-d = kg/kgBW/d) ^a	0.18	EPA (1993)
PF	Plant fraction	0	None listed as dietary intake in EPA (1993)
AF	Animal fraction	1	98% Aquatic vertebrates, lower Michigan, river (EPA 1993)
SF	Soil fraction	0	Not reported in EPA (1993); assumed to be negligible
IR _w	Water ingestion rate (g/g-d = L/kgBW/d)	0.045	Estimated (EPA 1993)

^aFood ingestion rate (g/g-d) reexpressed as kg/kgBW/d is assumed not to include ingested soil; therefore, PF+AF = 1.0.
EPA = U.S. Environmental Protection Agency.

The acceptable chronic dose of radiation to aquatic biota is 1 rad/d (NCRP 1991), and it is assumed that an acute dose 100 times that number is also acceptable. For birds, the acceptable chronic dose is 0.1 rad/d (IAEA 1992), while acute doses of 10 rad/d appear unlikely to cause long-term deleterious effects (IAEA 1992).

Table 2. Radiological Exposure Parameters for Ecological Radiological Constituents of Potential Concern

Ecological constituent of potential concern	Decay energy and absorption parameters						
	DCF ^a	E _a n _a ^b	F ^c	E _b n _b ^d	F ^e	E _g n _g ^f	F ^e
Radionuclides							
Cesium-134	9.50E-14	0.00E+00	1.00E+00	1.64E-01	1.00E+00	1.56E+00	4.10E-02
Cesium-137	1.29E-15	0.00E+00	1.00E+00	1.87E-01	1.00E+00	0.00E+00	1.00E+00
Cobalt-60	2.37E-11	0.00E+00	1.00E+00	9.70E-02	1.00E+00	2.50E+00	4.00E-02
Iodine-129	7.70E-14	0.00E+00	1.00E+00	6.40E-02	1.00E+00	2.50E-02	2.20E-01
Strontium-90	1.26E-15	0.00E+00	1.00E+00	1.96E-01	1.00E+00	0.00E+00	1.00E+00
Technetium-99	2.71E-16	0.00E+00	1.00E+00	1.01E-01	1.00E+00	0.00E+00	1.00E+00
Uranium-233	3.14E-15	4.82E+00	1.00E+00	1.30E-02	1.00E+00	2.00E-03	9.40E-01
Uranium-238	6.87E-16	4.19E+00	1.00E+00	1.00E-02	1.00E+00	1.00E-03	9.40E-01

^aDose conversion factor for immersion in water (Table III.2, Eckerman and Ryman 1993, converted to Sv/d per Bq/m³).

^bAlpha energy of the radionuclide (MeV) × proportion of disintegrations producing an a-particle (Table A.1, Eckerman and Ryman 1993).

^cAbsorbed fraction of energy E_a (assumed to be 1.0 for alpha radiations).

^dBeta energy of the radionuclide (MeV) × proportion of disintegrations producing a b-particle (Table A.1, Eckerman and Ryman 1993).

^eAbsorbed fraction of energy E_b or E_g (Blaylock, Frank, and O'Neal 1993; DOE 1997).

^fPhoton energy emitted during transition from a higher to a lower energy state (MeV) × proportion of disintegrations producing a g-particle (Table A.1, Eckerman and Ryman 1993).

AQUATIC BIOTA

The concentrations of potassium, sodium, and nitrate are high. The combined concentrations of these ions (ionic strengths) are 10.4 M (mole/L, where mole is defined as a number of grams equal to the molecular weight of the constituent) in Tank 26 and 14.1 M in Tank 28. Concentrations are similar in the other tanks. The pH in Tanks 26 and 28 is 8.4 and 7.3, respectively, but the pH in Tank 31 is 10 and in the other tanks is above 12. These ionic strengths and the pH in all tanks other than Tanks 26 and 28 would be immediately lethal to aquatic biota [the toxicity benchmark for sodium is ~0.03 M (Suter and Tsao 1996)]. Sufficient dilution and neutralization to prevent lethality are not likely before the slug of contaminants reaches White Oak Lake. Therefore, an approximately 1-km (0.6-mile) stretch of Melton Branch and White Oak Creek would be depopulated of aquatic biota. The slug of contaminants would probably pass into White Oak Lake in a day or two. Recovery and repopulation of the creek stretches would likely require up to one year as contaminants are flushed out by cleaner water from upstream.

External radiological exposures to water were estimated as described by Bechtel Jacobs (1998). Concentrations of radionuclides in tank water were divided by benchmark values for exposure of aquatic biota (or a benchmark for I-129 derived by the same methods). The hazard quotient (HQ) was calculated for each radionuclide and summed to determine the hazard index (HI) for each tank. These calculations are shown in Table 3. The HIs were approximately 8,900 for Tank 26 and 3,700 for Tank 28. However, the benchmarks were derived for chronic exposure, and the calculated exposures were predominantly internal, resulting from bioconcentration of radionuclides and ingestion of contaminated biota. Acute external exposures to water alone in Melton Branch would be negligible (Table 3).

Table 3. Radiological Exposure of Aquatic Biota to Radionuclides in Storage Tanks 26 and 28

Ecological constituent of potential concern	Tank 26					Tank 28			
	Bench-mark pCi/L	Tank conc. (Bq/mL)	RME (pCi/L)	HQ RME/ Bench-mark	External Dose ^a (rad/d)	Tank conc. (Bq/mL)	RME (pCi/L)	HQ RME/ Benchmark	External Dose (rad/d)
Radionuclides									
Cesium-134	5.98E+03	2.00E+04	7.40E+05	1.24E+02	5.64E-02	2.40E+03	8.88E+04	1.48E+01	6.77E-03
Cesium-137	5.93E+03	1.40E+06	5.18E+07	8.74E+03	0.00E+00	5.70E+05	2.11E+07	3.56E+03	0.00E+00
Cobalt-60	5.31E+03	2.20E+03	8.14E+04	1.53E+01	1.00E-02	3.70E+03	1.37E+05	2.58E+01	1.68E-02
Iodine-129	3.35E+05	7.80E-02	2.89E+00	8.62E-06	2.88E-09	1.90E-02	7.03E-01	2.10E-06	7.01E-10
Strontium-90	5.77E+04	2.50E+04	9.25E+05	1.60E+01	0.00E+00	1.50E+05	5.55E+06	9.62E+01	0.00E+00
Technetium-99	1.94E+06	1.90E+03	1.94E+06	1.00E+00	0.00E+00	4.10E+02	1.52E+04	7.82E-03	0.00E+00
Uranium-233	4.00E+03	3.80E+00	1.41E+02	3.52E-02	8.62E-10	6.08E+01	2.25E+03	5.62E-01	1.38E-08
Uranium-238	4.55E+03	1.00E-01	3.70E+00	8.13E-04	1.13E-11	1.80E+00	6.66E+01	1.46E-02	2.04E-10
			Sum	8.89E+03	6.64E-02			3.69E+03	2.36E-02

^aExternal dose = $5.11 \times 10^{-8} \times E_{\gamma} n_{\gamma} \times (1 - \Phi_{\gamma}) \times \text{RME}$ (Bechtel Jacobs 1998).

HQ = hazard quotient.

RME = reasonable maximum exposure.

Dilution of the contaminants in White Oak Lake would result (after complete mixing) in HIs of approximately 10 to 20 for Tank 26 and 4 to 8 for Tank 28. Therefore, chronic radiation toxicity to aquatic biota in White Oak Lake is likely. If the radionuclides were not retained by White Oak Dam and the downstream containment system, they would rapidly be diluted in the Clinch River below levels of concern for aquatic biota.

The time required to dilute contaminants in White Oak Lake can be estimated from the estimated flow rate and volume of the lake, assuming rapid mixing and a constant flow rate. The rate of loss of total mass of radionuclides ($-dM/dt$) is the product of the flow rate and the concentration at any given time ($F \times C$, where F is the flow rate and C is the concentration). C is defined as mass divided by volume, i.e., $C = M/V$ (where V is the total volume of the lake). Therefore, $-dM/dt = F \times M/V$. This formula is rearranged and integrated to find the mass (M) at any given time (t) relative to the starting mass (M_o):

$$\ln(M/M_o) = -t \times F/V ,$$

and

$$t = -\ln(M/M_o)/(F/V) .$$

Because F is assumed to be $1.3 \times 10^6 \text{ ft}^3/\text{d}$ and V is assumed to be $3 \text{ to } 6 \times 10^6 \text{ ft}^3$, F/V ranges between 0.2 and 0.4. To reduce the HI, which ranged from 8 to 20, to 1 requires a reduction of total mass to 1/4 to 1/20 of the initial mass, i.e., M/M_o ranges from 0.05 to 0.25. Substituting into the second equation above, the time t required to dilute the contaminants in White Oak Lake below the radiological benchmark is from 3 to 15 days. If mixing with fresh water entering the lake is slow, parts of the lake will require longer for concentrations to drop below benchmark levels.

HERONS

Radiological doses to herons were estimated by using methods described by Sample et al. (1997). Chronic and acute external radiation doses were assumed to result from standing in or near the contaminated water for half of each day. Chronic internal radiation doses were assumed to result from ingestion of fish contaminated by uptake of radionuclides from contaminated water. It was assumed that acute internal doses would not occur because uptake of radionuclides to levels described by the bioaccumulation factor (BCF) is a result of chronic exposure.

Results of exposure calculations are shown in Table 4 for Tank 26 and Table 5 for Tank 28. The calculations showed that external radiation would provide doses of 11 and 19 rad/d to herons standing for half of the day in or at the edge of the water. These doses are above the nominal acute dose of 10 rad/d that is assumed (IAEA 1992) not to cause adverse reproductive effects to birds. The likelihood that a heron would spend half a day exposed to this spill is probably low, but sufficient exposure to cause some harm seems to be possible.

The chronic benchmark for birds is 0.1 rad/d (IAEA 1992). Combined external and internal radiation HIs were about 1,900 for Tank 26 and 3,850 for Tank 28. Dilution of the contaminants in White Oak Lake would reduce radionuclide HIs to approximately 2 to 4 for Tank 26 and 4 to 8 for Tank 28. Therefore, chronic radiation toxicity to herons and other fish-eating predators in White Oak Lake is possible. If the radionuclides were not retained by White Oak Dam and the downstream containment system, they would rapidly be diluted in the Clinch River below levels of concern for herons and other fish-eating predators.

Using the equation developed for aquatic biota and a required reduction in mass of radionuclides of 1/2 to 1/8, the time required to bring HIs in White Oak Lake below 1 would be 2 to 10 days, or longer if mixing with clean water entering the lake is not rapid.

SUMMARY AND CONCLUSIONS

If one of the Melton Valley TRU-waste storage tanks ruptures and releases 50,000 gal of liquid radioactive waste into Melton Branch, aquatic biota would be killed by chemical toxicity, perhaps by high pH, and possibly by acute external radiation exposure. Herons and other fish-eating biota could be harmed by acute external radiation exposure if they remain in close proximity to the released water, which seems unlikely since the rapidly flowing nature of the water would not provide suitable conditions for a predator to fish.

The contaminants would likely move quickly downstream to White Oak Creek, where radiation toxicity is also probable. Dilution of the non-radioactive contaminants in White Oak Lake would rapidly reduce the concentrations of contaminants below levels causing chemical toxicity, and the pH would probably change to non-toxic levels. However, chronic radiation doses to aquatic biota and fish-eating predators in White Oak Lake would remain above benchmarks for acceptable chronic radiation levels for a few days to a few weeks. The predominant exposures are to cesium-137 from Tank 26 or cesium-137, cobalt-60, and strontium-90 from Tank 28.

Dilution of contaminants by release into the Clinch River would reduce radiation doses to aquatic biota and fish-eating predators to acceptable levels.

Table 4. Radiological Exposure of Great Blue Herons to Radionuclides in Storage Tank 26

Ecological constituent of potential concern	Tank conc. (Bq/mL)	RME (pCi/L)	BCF (L/kg)	BAFv	ADDA (pCi/gBW/d) RME × BCF × IA /1,000	ADDW (pCi/gBW/d) RME × IRW /1,000	ADDtotal (pCi/gBW/d) ADDP + ADDA + ADDS	Internal Dose (rad/d)	External Dose (rad/d)	Total Dose (rad/d) Internal + External	TRV (rad/d)	Site HQ ADD total / TRV
Radionuclides												
Cesium-134	2.00E+04	7.40E+05	2.00E+03	1.00E+00	2.66E+05	3.33E+01	2.66E+05	3.11E+00	4.16E-01	3.52E+00	1.00E-01	3.52E+01
Cesium-137	1.40E+06	5.18E+07	2.00E+03	1.00E+00	1.86E+07	2.33E+03	1.87E+07	1.79E+02	3.95E-01	1.79E+02	1.00E-01	1.79E+03
Cobalt-60	2.20E+03	8.14E+04	3.30E+02	1.00E+00	4.84E+03	3.66E+00	4.84E+03	4.88E-02	1.14E+01	1.15E+01	1.00E-01	1.15E+02
Iodine-129	7.80E-02	2.89E+00	5.00E+01	3.50E-01	2.60E-02	1.30E-04	2.61E-02	3.25E-08	1.32E-06	1.35E-06	1.00E-01	1.35E-05
Strontium-90	2.50E+04	9.25E+05	5.00E+01	1.50E-02	8.33E+03	4.16E+01	8.37E+03	1.26E-03	6.91E-03	8.17E-03	1.00E-01	8.17E-02
Technetium-99	1.90E+03	1.94E+06	1.50E+01	4.25E-01	5.24E+03	8.73E+01	5.33E+03	1.17E-02	3.12E-03	1.48E-02	1.00E-01	1.48E-01
Uranium-233	3.80E+00	1.41E+02	5.00E+01	1.00E-02	1.27E+00	6.33E-03	1.27E+00	6.27E-05	2.62E-06	6.54E-05	1.00E-01	6.54E-04
Uranium-238	1.00E-01	3.70E+00	5.00E+01	1.00E-02	3.33E-02	1.67E-04	3.35E-02	1.44E-06	1.50E-08	1.45E-06	1.00E-01	1.45E-05
											HI =	1.94E+03

RME = Reasonable maximum exposure.

BCF = Water-to-animal bioconcentration factor (Bechtel Jacobs 1998).

BAFv = Food-to-predator bioaccumulation factor (Baes et al. 1984).

ADDA = Average daily ingestion rate of animal tissue.

1,000 = Conversion from kilogram to gram body weight.

IA (kg/kgBW/d) = Animal ingestion rate.

ADDW = Average daily ingestion rate; drinking water.

IRW (L/kgBW/d) = Water ingestion rate.

ADDtotal = Average daily ingestion rate; total.

Internal Dose (rad/d) = $CF1 \times ADD_{total} \times [(20 \times E_{an_a}) + (E_{bn_b} \times F_b) + (E_{gn_g} \times F_g)]$.External Dose (rad/d) = $RME \times F_{above} \times DCF \times CF2 \times 2$.CF = Conversion factor, 5.11×10^{-8} . F_{above} = Fraction of time spent at or in proximity to the water surface = 0.5.CFa = Conversion factor, 5.92×10^6 .

2 = Conversion factor for closer proximity of heron to external source than of humans, for whom parameters were derived (Bechtel Jacobs 1998).

TRV = Toxicity reference value.

HQ = Hazard quotient.

HI = Hazard index.

Table 5. Radiological Exposure of Great Blue Herons to Radionuclides in Storage Tank 28

Ecological constituent of potential concern	Tank conc. (Bq/mL)	RME (pCi/L)	BCF	BAFv	ADDA (pCi/gBW/d) RME × BCF × IA /1,000	ADDW (pCi/gBW/d) RME × IRW /1,000	ADDtotal (pCi/gBW/d) ADDP + ADDA + ADDS	Internal Dose (rad/d)	External Dose (rad/d)	Total Dose (rad/d) Internal + External	TRV (rad/d)	Site HQ ADD total/ TRV
Radionuclides												
Cesium-134	2.40E+03	8.88E+04	1.00E+04	1.00E+00	1.60E+05	4.00E+00	1.60E+05	1.86E+00	5.00E-02	1.91E+00	1.00E-01	1.91E+01
Cesium-137	5.70E+05	2.11E+07	1.00E+04	1.00E+00	3.80E+07	9.49E+02	3.80E+07	3.63E+02	1.61E-01	3.64E+02	1.00E-01	3.64E+03
Cobalt-60	3.70E+03	1.37E+05	1.50E+03	1.00E+00	3.70E+04	6.16E+00	3.70E+04	3.73E-01	1.92E+01	1.96E+01	1.00E-01	1.96E+02
Iodine-129	1.90E-02	7.03E-01	2.00E+02	3.50E-01	2.53E-02	3.16E-05	2.53E-02	3.16E-08	3.20E-07	3.52E-07	1.00E-01	3.52E-06
Strontium-90	1.50E+05	5.55E+06	3.00E+02	1.50E-02	3.00E+05	2.50E+02	3.00E+05	4.52E-02	4.14E-02	8.66E-02	1.00E-01	8.66E-01
Technetium-99	4.10E+02	1.52E+04	1.00E+02	4.25E-01	2.73E+02	6.83E-01	2.74E+02	6.02E-04	2.44E-05	6.26E-04	1.00E-01	6.26E-03
Uranium-233	6.08E+01	2.25E+03	5.00E+01	1.00E-02	2.02E+01	1.01E-01	2.03E+01	1.00E-03	4.19E-05	1.05E-03	1.00E-01	1.05E-02
Uranium-238	1.80E+00	6.66E+01	5.00E+01	1.00E-02	5.99E-01	3.00E-03	6.02E-01	2.58E-05	2.71E-07	2.61E-05	1.00E-01	2.61E-04
											HI =	3.85E+03

RME = Reasonable maximum exposure.

BCF = Water-to-animal bioconcentration factor (Bechtel Jacobs 1998).

BAFv = Food-to-predator bioaccumulation factor (Baes et al. 1984).

ADDA = Average daily ingestion rate of animal tissue.

1,000 = Conversion from kilogram to gram body weight.

IA (kg/kgBW/d) = Animal ingestion rate.

ADDW = Average daily ingestion rate; drinking water.

IRW (L/kgBW/d) = Water ingestion rate.

ADDtotal = Average daily ingestion rate; total.

Internal Dose (rad/d) = $CF1 \times ADD_{total} \times [(20 \times E_{\alpha n_{\alpha}}) + (E_{\beta n_{\beta}} \times \Phi_{\beta}) + (E_{\gamma n_{\gamma}} \times \Phi_{\gamma})]$.External Dose (rad/d) = $RME \times F_{above} \times DCF \times CF2 \times 2$.CF = Conversion factor, 5.11×10^{-8} . F_{above} = Fraction of time spent at or in proximity to the water surface = 0.5.CFa = Conversion factor, 5.92×10^6 .

2 = Conversion factor for closer proximity of heron to external source than of humans, for whom parameters were derived (Bechtel Jacobs 1998).

TRV = Toxicity reference value.

HQ = Hazard quotient.

HI = Hazard index.

REFERENCES

- Baes, C. F., III, R. D. Sharp, A. L. Sjoren, and R. W. Shor 1994. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL-5786, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Bechtel Jacobs (Bechtel Jacobs Company LLC) 1998. *Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at Oak Ridge National Laboratory, Oak Ridge, Tennessee*, BJC/OR-80, Bechtel Jacobs Company LLC, Oak Ridge, Tennessee.
- Blaylock, B. G., M. L. Frank, and B. R. O'Neal 1993. *Methodology for Estimating Radiation Dose Rates to Freshwater Biota Exposed to Radionuclides in the Environment*, ES/ER/TM-78, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- DOE (U.S. Department of Energy) 1997. *Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee*, DOE/OR/01-1455/V6&D2.
- Eckerman, K. F., and J. C. Ryman 1993. *External Exposure to Radionuclides in Air, Water, and Soil*, EPA 402-R-93-081, Federal Guidance Report No. 12, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C.
- EPA (U.S. Environmental Protection Agency) 1993. *Wildlife Exposure Factors Handbook*, Volume I, EPA/600/R-93/187a, Office of Research and Development, Washington, D.C.
- IAEA (International Atomic Energy Agency) 1992. *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*, IAEA Technical Report Series 332, Vienna, Austria.
- Keeler, J. M., J. M. Giaquinto, and A. M. Meeks 1996. *Characterization of the MVST Waste Tanks Located at ORNL*, ORNL/TM-13357, Lockheed Martin Energy Research Corp., Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Loar, J. M., et al. 1992. *First Annual Report on the Biological Monitoring and Abatement Program at the Oak Ridge National Laboratory*, ORNL/TM 10399, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- NCRP (National Council on Radiation Protection) 1991. *Effects of Ionizing Radiation on Aquatic Organisms*, NCRP Report No. 109, National Council on Radiation Protection and Measurements, Bethesda, Maryland.
- Sample, B. E., M. S. Aplin, R. A. Efroymson, G. W. Suter II, and C. J. E. Welsh 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*, ORNL/TM-13391, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Suter, G. W. II, and C. L. Tsao 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*, ES/ER/TM-96/R2, Lockheed Martin Energy Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F.3

IMPACTS TO SOIL AND GROUNDWATER FROM A SEISMICALLY INDUCED BREACH OF THE MELTON VALLEY STORAGE TANKS

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F.3

IMPACTS TO SOIL AND GROUNDWATER BY A SEISMICALLY INDUCED BREACH OF THE MELTON VALLEY STORAGE TANKS

1. CONCENTRATION CONVERSIONS

Strontium-90 was considered a representative constituent of concern (COC) to evaluate under the potential release scenario. Strontium-90 is a major COC and has significant environmental impact. Furthermore, strontium-90 in Tank W28, one tank with more heavily impacted wastes, accounts for approximately 15% of the total radioactive material (with respect to curies) in the tank. According to Keeler et al. (1996), strontium-90 concentrations in Tank W28 are **1.5E5 Becquerel/mL**. Assuming the analytical results reported in Keeler et al. (1996) are representative of the entire 50,000-gallon waste volume, this can be converted via equations taken from the U.S. Department of Health, Education and Welfare (1970):

$$\begin{aligned} & 1.5\text{E}5 \text{ B/mL} \times 2.7\text{E-}11 \text{ curies/1B} \times 1 \text{ g/141 curies} \\ & = 2.87\text{E-}8 \text{ g/mL} \times 1,000 \text{ mL/L} \\ & = 2.87\text{E-}5 \text{ g/L} \\ & = \mathbf{2.87\text{E-}2 \text{ mg/L}} \end{aligned}$$

2. ESTIMATE TOTAL MASS OF RELEASE

$$\begin{aligned} \text{Total Mass} &= 2.87\text{E-}2 \text{ mg/L} \times 50,000 \text{ gallons released} \times 3.7859 \text{ L/gal} \\ &= 5,432.7665 \text{ mg} \\ &= \mathbf{5.433 \text{ grams of strontium-90 or 766 curies}} \end{aligned}$$

3. HOLDING CAPACITY OF THE SOIL

Assuming a reasonable worst-case scenario with respect to impact to the soil and groundwater, the extent of contaminant loading to the soil can be estimated. This can be done by evaluating the partitioning effect between the solute (waste) and the aquifer material. For such a calculation, it will be assumed that flow from the release would move as porous media flow and at such a rate that the system kinetics would allow the system to remain in chemical equilibrium (the conceptual model for the release scenario along with the potential resulting area of impacted soils is detailed in Figure 1).

To evaluate the partitioning relationship, consider the aquifer or soil media's distribution coefficient (Kd):

$$Kd = \text{concentration of the COC on the solid/concentration of the COC in solution.}$$

For strontium-90, a value of **20 L/kg** was used as suggested by Sheppard and Thibault (1990) for loam soils.

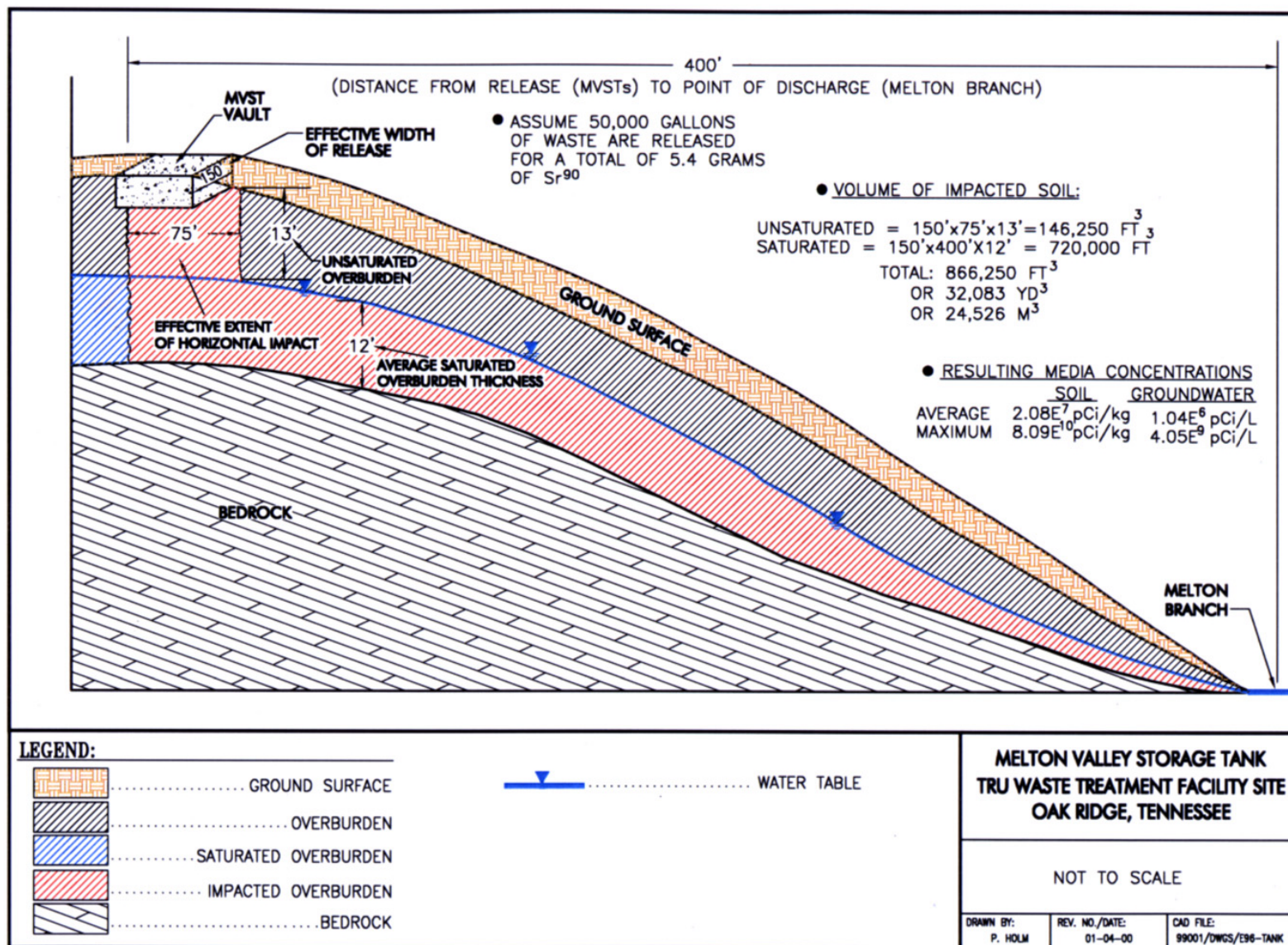


Figure 1. Conceptual Model for Melton Valley Storage Tank Release Scenario

Can the estimated area of contaminated soil adsorb the estimated quantity of strontium-90 that would be released? What is the soil's holding capacity?

As from the previous equation,

$$\begin{aligned}\text{Concentration of the COC on the solid} &= K_d \times \text{concentration of the COC in solution} \\ \text{Holding capacity} &= 20 \text{ L/kg} \times 2.87\text{E-}2 \text{ mg/L} \\ &= \mathbf{0.574 \text{ mg/kg}} \text{ (this is also the max. concentration to be expected in the soil)}\end{aligned}$$

if, as indicated on Figure 1, we could potentially have **866,250 ft³** of impacted soils, then:

$$\begin{aligned}\text{kilograms of potentially impacted soil} &= 866,250 \text{ ft}^3 \times 93.65 \text{ lb/ft}^3 \times 0.45359 \text{ kg/lb} \\ &= 3.68\text{E}7 \text{ kilograms (assuming a bulk density of } 1.5 \text{ g/cm}^3\text{)}\end{aligned}$$

Effective Holding Capacity of the soil

$$\begin{aligned}&= \text{maximum concentration of the COC on the solid} \times \text{total mass of potentially impacted soil} \\ &= 0.574 \text{ mg/kg} \times 3.68\text{E}7 \text{ kg} \\ &= 2.11\text{E}7 \text{ mg} \\ &= 2.11\text{E}4 \text{ g} \\ &= \mathbf{21.12 \text{ kg}}\end{aligned}$$

Based on past release information from the Melton Valley Storage Tanks area, such a release would greatly increase the level of localized impact.

4. FIRST-ORDER DECAY RATES FOR AN INDICATIVE CONSTITUENT OF CONCERN

As demonstrated previously, the rate of groundwater flushing from the impacted soil can be determined from the K_d equation. However, such a calculation is greatly dependent upon contaminant distribution, groundwater recharge, and flow rates. The concentration in the soil will also be directly dependent upon the radio decay coefficient of the constituent of concern (**29 years** for strontium-90 as referenced by Walton 1985).

The resulting concentration 100 years after release can be predicted by the following equation:

$$\begin{aligned}\text{Resulting mass} &= \text{original mass } e^{-\lambda t} \\ \text{Where: } \lambda &= -0.6931 / 29 \\ &= -0.0239 \\ t &= 100 \text{ years}\end{aligned}$$

$$\begin{aligned}\text{Therefore, resulting mass} &= 5.433 \text{ g} \times e^{-2.92} \\ &= \mathbf{0.498 \text{ g}} \text{ (over a 90\% reduction in total mass in 100 years).}\end{aligned}$$

Consequently, the radioactive decay process alone will greatly impact the strontium-90 mass and, correspondingly, soil and groundwater concentration after 100 years.

5. RESULTING CONCENTRATIONS IN SOIL AND GROUNDWATER

Based on the previously outlined assumptions, it is possible to calculate a reasonable maximum concentration in both groundwater and soil as well as average concentrations if the strontium-90 is evenly distributed across the suspected area of impact.

	Soil:	Groundwater:
<i>Average</i>	$5.433 \text{ g}/3.68\text{E}7 \text{ kg}$ $= 1.476\text{E}-7 \text{ g/kg}$ $= 1.476\text{E}-4 \text{ mg/kg}$ $= 1.476\text{E}-4 \text{ mg/kg} \times 141 \text{ Ci/g}$ $= 2.08\text{E}-5 \text{ Ci/kg}$ $= 2.08\text{E}7 \text{ pCi/kg}$	$= \text{soil conc.} / K_d$ $= 1.476\text{E}-4 \text{ mg/kg} / 20 \text{ L/kg}$ $= 7.38\text{E}-6 \text{ mg/L}$ $= 7.38\text{E}-9 \text{ g/L} \times 141 \text{ Ci/g}$ $= 1.04\text{E}-6 \text{ Ci/L}$ $= 1.04\text{E}6 \text{ pCi/L}$
<i>Maximum</i>	0.574 mg/kg $= 5.74\text{E}-4 \text{ g/kg} \times 141 \text{ Ci/g}$ $= 8.09\text{E}-2 \text{ Ci/kg}$ $= 8.09\text{E}10 \text{ pCi/kg}$	$= \text{soil conc.} / K_d$ $= 0.574 \text{ mg/kg} / 20 \text{ L/kg}$ $= 0.0287 \text{ mg/L}$ $= 2.87\text{E}-5 \text{ g/L} \times 141 \text{ Ci/g}$ $= 4.05\text{E}-3 \text{ Ci/L}$ $= 4.05\text{E}9 \text{ pCi/L}$

6. NARRATIVE AND CONCLUSIONS

In the event of the rupture and subsequent release of the contents of one of the eight Melton Valley Storage Tanks, up to 50,000 gallons of liquid waste could be released to the environment. In this appendix, the consequential impacts of such a release have been evaluated with respect to potential impact to the soil and groundwater. To evaluate such a release scenario, it was assumed that waste would leak from the vault in a band as wide as 150 ft across the lower front edge of the vault, in a zone parallel to slope down to Melton Branch. Furthermore, it was assumed that the waste would initially leak through the unsaturated overburden impacting an area of soil (150 ft \times 75 ft \times 13 ft) prior to reaching the groundwater surface. Once the waste reaches the water table/groundwater surface, it is further assumed that waste would mix with the shallow groundwater and ultimately discharge out to Melton Branch approximately 400 ft away. Details of this conceptual model are depicted in Figure 1. Such a release could potentially impact 5573.6 m² (0.557 hectares) of area and 24,526 m³ of soil.

In order to assess the environmental impact, it was assumed that one of the more heavily impacted tanks, W28, would breach and spill its entire contents (approximately 50,000 gallons). Strontium-90 concentrations in this tank were reported in Keeler et al. (1996) to be 1.5E5 Becquerel/mL. This concentration in Tank W28 indicates that strontium-90 reflects approximately 15% of the total radioactive material in that tank (as measured in Becquerels). Assuming the concentrations reported are accurate for all the waste in Tank W28, 766 curies of strontium-90 would be released to the environment. If that mass of strontium-90 were evenly distributed across the potentially impacted area, concentrations in soil and groundwater would equate to 2.08E7 pCi/kg and 1.04E6 pCi/L, respectively. Based on assumed soil/water partitioning interactions, the maximum values that could be expected in soil and groundwater would equal 8.09E10 pCi/kg and 4.05E9 pCi/L, respectively. All calculations are detailed in this appendix.

These resulting concentrations are significant, as little to any previous impact for strontium-90 has been reported for the soil and groundwater near the proposed transuranic (TRU) waste treatment facility and South of Melton Branch. Furthermore, these concentrations reflect an apparent driver for remediation when compared to the 10^{-6} residential risk scenario values of 0.014 pCi/kg and 0.85 pCi/L for soil and water (RAIS 2000).

7. REFERENCES

- Walton, W. 1985. *Practical Aspects of Ground Water Modeling*, Second Edition, National Water Well Association, Worthington, Ohio.
- Sheppard, M. I., and D. H. Thibault 1990. "Default Soil Solid/Liquid Partition Coefficient, K_d 's for Four Major Soil Types, A Compendium," *Health Physics* **59**(4).
- Keeler, J. M., J. M. Giaquinto, and A. M. Meeks 1996. *Characterization of the MVST Waste Tanks Located at Oak Ridge National Laboratory*, ORNL/TM-13357, Contract No. DE-AC05-96OR22464, Lockheed Martin Energy Research Corp., Oak Ridge, Tennessee.
- U.S. Department of Health, Education and Welfare 1970. *Radiological Health Handbook*, Public Health Service, Food and Drug Administration, Bureau of Radiological Health, Rockville, Maryland.
- RAIS 2000. *Risk Assessment Information System*, 1/11/2000. Information as located on the world wide web (http://risk/lcd.ornl.gov/prg/prg_search.html).

THIS PAGE INTENTIONALLY LEFT BLANK